Atty. Dkt. 3693-50
S03-CB366US1

U.S. PATENT APPLICATION

Inventor(s): Hirotaka NIIYA

Invention: SEMI-TRANSMISSIVE DISPLAY APPARATUS

NIXON & VANDERHYE P.C.
ATTORNEYS AT LAW
1100 NORTH GLEBE ROAD, 8TH FLOOR
ARLINGTON, VIRGINIA 22201-4714
(703) 816-4000
Facsimile (703) 816-4100

SPECIFICATION

SEMI-TRANSMISSIVE DISPLAY APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a semi-transmissive display apparatus, and more particularly to a display apparatus having a color-filter-on-array structure, in which the switching devices and the color filter are provided on the same substrate.

2. Description of the Background Art

Liquid crystal display apparatuses are a type of display apparatus that has been attracting public attention. For their advantageous features such as a small thickness and a small power consumption, they have been used in a wide variety of applications, including OA equipment such as personal computers, camcorders equipped with liquid crystal display monitors, and portable information devices such as mobile phones, and PDAs (Personal Digital Assistants).

A common liquid crystal display apparatus includes a device substrate on which pixel electrodes are arranged in a matrix pattern, and a counter substrate including a color filter having filter portions of three primary colors (red, green and blue) and a black matrix for optically separating filter portions of different colors from one another. The device substrate and the counter substrate are attached to each other so that elements on one substrate are aligned with those on the other, i.e., so that the pixel electrodes on the device substrate and the filter portions of the color filter on the counter substrate are precisely aligned with each other.

In order to properly attach the device substrate and the counter substrate to each other, it is necessary to provide some attachment margin for accommodating possible

displacements. Therefore, it is usually the case that the light-blocking black matrix covering the gaps between filter portions of different colors extends so as to overlap the pixel electrodes on the opposing device substrate by a few microns. Thus, there is a design limitation on the aperture ratio of a liquid crystal display apparatus.

Moreover, in order to realize a high-definition display, it is necessary to reduce the size of one pixel, which is the minimum element of an image. However, as the size of one pixel decreases, the lines, the switching devices, the black matrix, etc., occupy a greater area with respect to the total area of the pixel. Thus, reducing the size of one pixel also reduces the aperture ratio.

In view of this, another type of liquid crystal display apparatuses aiming at increasing the definition and the aperture ratio have been proposed in the art, as disclosed in Japanese Laid-Open Patent Publication No. 2-54217.

Japanese Laid-Open Patent Publication No. 2-54217 discloses a liquid crystal display apparatus employing a so-called "color-filter-on-array structure", in which the color filter is provided on the same substrate where the switching devices are provided.

The display device will now be described more specifically with reference to FIG. **4**.

A liquid crystal display apparatus **30** includes a counter substrate **22**, a TFT array substrate **23**, and a liquid crystal layer **12** interposed therebetween. The counter substrate **22** includes a glass substrate **11** and a common counter electrode **10**, and the TFT array substrate **23** includes TFTs (Thin Film Transistors) **24** as switching devices provided thereon.

In the TFT array substrate **23**, the TFT **24**, including a gate electrode **1**, a source electrode **4**, a drain electrode **5**, etc., is provided on the glass substrate **11**, and a black matrix **7** is provided over the TFT **24**, with a color filter **9** being provided on the glass substrate **11** except for where the TFT **24** is provided. Moreover, a pixel electrode **8**,

connected to the drain electrode **5** of the TFT **24**, is provided over the black matrix **7** and the color filter **9**.

In the liquid crystal display apparatus **30**, the pixel electrode **8** and the color filter **9** are integrated together, whereby there is little displacement between the pixel electrode **8** and the corresponding filter portion of the color filter **9**, thus minimizing the line width of the black matrix **7**. In the example illustrated in FIG. **4**, the black matrix **7** is provided so as to cover the TFT **24**, whereby it functions also as a light-blocking film for the TFT **24**. On the other hand, the counter substrate **22** to be attached to the TFT array substrate **23** has a simple structure where the common counter electrode **10** is provided on the glass substrate **11**, and is not structurally divided into pixels. Therefore, this structure hardly requires any attachment margin. Thus, it is possible to realize a display apparatus that has both a high definition and a high aperture ratio.

This is an example where a color-filter-on-array structure is applied to a transmissive liquid crystal display apparatus.

However, a transmissive liquid crystal display apparatus typically includes a backlight, which consumes 50% or more of the total amount of power consumed. Therefore, the provision of a backlight significantly increases the total power consumption.

In view of this, reflective liquid crystal display apparatuses, which make use of the reflection of the ambient light and consume less power, are also widely used in the art. Japanese Laid-Open Patent Publication No. 2000-162625 discloses a reflective liquid crystal display apparatus employing a color-filter-on-array structure.

The display apparatus will now be described more specifically with reference to FIG. 5.

In the TFT array substrate **23** of the liquid crystal display apparatus **30**, a reflective electrode **20** connected to the drain electrode **5** of the TFT **24** is provided on an interlayer insulating film **14**, and the transparent electrode **8** connected to the reflective

electrode **20** is provided over the reflective electrode **20**, with the color filter **9** being provided between the electrodes.

In the liquid crystal display apparatus **30**, as in the previous example of a transmissive display apparatus, the pixel electrode **8** and the color filter **9** are integrated together, whereby there is little displacement between the pixel electrode **8** and the corresponding filter portion of the color filter **9**, thus minimizing the line width of the black matrix 7. On the other hand, the counter substrate **22** to be attached to the TFT array substrate **23** has a simple structure where the common counter electrode **10** is provided on the glass substrate **11**, and is not structurally divided into pixels. Therefore, this structure hardly requires any attachment margin. Thus, it is possible to realize a display apparatus that has both a high definition and a high aperture ratio.

This is an example where a color-filter-on-array structure is applied to a reflective liquid crystal display apparatus.

However, a reflective liquid crystal display apparatus has a disadvantage in that the visibility thereof is very low when used in environments with little ambient light. In view of this, Japanese Laid-Open Patent Publication No. 11-101992 discloses a semi-transmissive liquid crystal display apparatus capable of displaying an image both in a transmissive mode and in a reflective mode with a high aperture ratio, though it does not employ a color-filter-on-array structure.

Japanese Laid-Open Patent Publication No. 11-101992 states that the disclosed display apparatus employs a semi-transmissive arrangement having transmissive regions and reflective regions, thereby allowing for the omission of a black matrix, which is normally provided on the counter substrate, thus realizing a high aperture ratio.

However, this arrangement only allows for the omission of a black matrix, and not the omission of a color filter, which is also normally provided on the counter substrate. It is still necessary to provide a color filter on the counter substrate. Therefore, the TFT

array substrate and the counter substrate need to be attached to each other so that the pixel electrodes on the TFT array substrate are aligned with the filter portions of the color filter on the counter substrate, thus requiring some attachment margin.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a semi-transmissive display apparatus having a high definition and a high aperture ratio, by employing a color-filter-on-array structure in a semi-transmissive display apparatus.

In order to achieve the object set forth above, the present invention provides a semi-transmissive display apparatus, in which a plurality of pixels, each including a transmissive region and a reflective region, are arranged in a matrix pattern, the apparatus including: a device substrate including, for each of the plurality of pixels, a transparent electrode forming the transmissive region, a reflective plate forming the reflective region, and a switching device; a counter substrate including a common counter electrode and opposing the device substrate; and a display layer interposed between the device substrate and the counter substrate, wherein the device substrate is provided with a color filter.

In this structure, the color filter and the transparent electrode are provided on the device substrate, whereby there is little displacement between the transparent electrode and the color filter, while eliminating the need to provide the color filter on the counter substrate. Therefore, the counter substrate has a simple structure where the common counter electrode is provided on the substrate. Therefore, this structure hardly requires any attachment margin when attaching the substrates to each other. Furthermore, this structure eliminates the need to provide a black matrix for optically separating filter portions of different colors of the color filter from one another, thereby realizing a display apparatus having a high definition and a high aperture ratio.

In one embodiment, the transparent electrode is provided closer to the display

layer than the color filter so as to cover the color filter, whereas the reflective plate is provided farther away from the display layer than the color filter and the transparent electrode so as to cover the switching device.

In this structure, the transparent electrode is provided on one side of the color filter that is closer to the display layer, whereby it is possible to apply a voltage across the display layer between the transparent electrode of the device substrate and the common counter electrode of the counter substrate. Moreover, the reflective plate is provided on one side of the color filter that is closer to the switching device so as to cover the switching device, whereby the reflective plate functions as a light-blocking film for the switching device, thereby suppressing the decrease in the switching characteristics of the switching device due to light.

In one embodiment, an interlayer insulating film is provided between the color filter and the transparent electrode so as to cover the reflective plate, and a thickness of the interlayer insulating film is determined so that a total optical path length for light traveling through the transmissive region is substantially equal to that for light traveling through the reflective region.

In a semi-transmissive display apparatus, the total optical path length for light traveling through the transmissive region is significantly different from that for light traveling through the reflective region. Specifically, light passes through the liquid crystal layer twice in the reflective region, whereas light passes through the liquid crystal layer only once in the transmissive region. Thus, there is a significant difference between the total optical path length in the transmissive region and that in the reflective region, thereby lowering the display quality. In the structure described above, the interlayer insulating film is provided between the color filter and the transparent electrode so as to cover the reflective plate, and the thickness thereof is determined so that the total optical path length for light traveling through the transmissive region is substantially equal to that

for light traveling through the reflective region. Thus, in a color-filter-on-array structure, the optical path length in the transmissive region and that in the reflective region can be made substantially equal to each other, whereby it is possible to maintain a desirable display quality without causing a phase difference between the transmissive region and the reflective region.

In one embodiment, the interlayer insulating film is made of a resin.

With this structure, it is possible to easily form an interlayer insulating film having a thickness on the order of μm, which is required for matching the total optical path length for light traveling through the transmissive region and that for light traveling through the reflective region.

In one embodiment, the reflective plate is electrically connected to neither the switching device nor the transparent electrode.

With this structure, the reflective plate is in a floating structure, where it is electrically connected to neither the switching device nor the pixel electrode. In this way, the parasitic capacitance is small and the operation of the switching device is not adversely influenced. Thus, it is possible to realize a semi-transmissive liquid crystal display apparatus having a simple color-filter-on-array structure.

In one embodiment, the switching device is provided farther away from the display layer than the color filter, and the transparent electrode is electrically connected to the switching device via a contact hole formed in the color filter layer.

With this structure, the transparent electrode and the switching device can be connected to each other by a common method, and a desirable conductivity can be provided between the switching device and the transparent electrode layer.

Other objects, features, and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic plan view illustrating a pixel region of a liquid crystal display apparatus according to Embodiment 1 of the present invention.

FIG. **2** is a schematic cross-sectional view illustrating a liquid crystal display apparatus according to Embodiment 2 of the present invention, taken along line II-II in FIG. **1**.

FIG. **3** is a schematic cross-sectional view illustrating a liquid crystal display apparatus according to Embodiment 1 of the present invention, taken along line II-II in FIG. **1**.

FIG. **4** is a schematic cross-sectional view illustrating a conventional transmissive liquid crystal display apparatus employing a color-filter-on-array structure.

FIG. **5** is a schematic cross-sectional view illustrating a conventional reflective liquid crystal display apparatus employing a color-filter-on-array structure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be described in detail with reference to the drawings. The following embodiments are directed to a semi-transmissive liquid crystal display apparatus of a TFT-driven type, in which TFTs are used as switching devices. Note however that the liquid crystal display apparatus of the present invention is not limited thereto, and the present invention can be applied to any other suitable liquid crystal display apparatus of an active matrix-driven type, in which switching devices other than TFTs are used. Moreover, the present invention can also be applied to any suitable display apparatus other than liquid crystal display apparatuses.

EMBODIMENT 1

A semi-transmissive liquid crystal display apparatus according to Embodiment 1 of the present invention will now be described with reference to FIG. **1** and FIG. **3**. Note that FIG. **1** is a schematic plan view illustrating a pixel region of a TFT array substrate **23** of a liquid crystal display apparatus **30** according to Embodiment 1 of the present invention, and FIG. **3** is a schematic cross-sectional view taken along line II-II in FIG. **1**.

The liquid crystal display apparatus **30** includes the TFT array substrate **23**, a counter substrate **22** provided so as to oppose the TFT array substrate **23**, and a liquid crystal layer **12** provided so as to be interposed between the substrates.

The TFT array substrate **23** includes a plurality of gate lines **17** provided so as to extend parallel to each other on a glass substrate **11**, a plurality of source lines **18** provided so as to extend parallel to each other in a direction perpendicular to the gate lines **17**, and a TFT **24** provided at each intersection between the gate line **17** and the source line **18**. The TFT array substrate **23** further includes a reflective plate **13**, a color filter **9** and a transparent electrode **8**, which are to be described later.

The gate line **17** is made of titanium, or the like. Moreover, storage capacitor lines **19** are provided so as to extend parallel to each other between the gate lines **17**. Furthermore, a gate insulating film **2** made of silicon nitride, or the like, is provided so as to cover the gate line **17** and the storage capacitor line **19**.

The storage capacitor line **19** is made of the same material as the gate line **17** and is form in the same layer as the gate line **17**. The storage capacitor line **19** is connected to a drain electrode **5** of the TFT **24** to be described later, forming a storage capacitor. Normally, when the pixel capacitor for storing a charge is made up only of the liquid crystal capacitor, the image-holding capability may be insufficient and the influence of the parasitic capacitance may be significant. Therefore, the storage capacitor is provided in order to ensure a sufficient display-data-holding capability and a desirable

image display operation.

The source line **18** is made of titanium, or the like, and is provided on the gate insulating film **2**.

The TFT **24** includes a gate electrode **1** being a protruding portion of the gate line **17**, a semiconductor film **3**, a source electrode **4** being a protruding portion of the source line **18** and extending over the semiconductor film **3**, and the drain electrode **5** extending over the semiconductor film **3** so as to oppose the source electrode **4**. Furthermore, a protection film **6** made of silicon nitride, or the like, is provided so as to cover the TFT **24**.

The semiconductor film **3** is provided over the gate electrode **1** with the gate insulating film **2** being interposed therebetween, and includes an intrinsic amorphous silicon layer **3b** on the gate insulating film **2** and an n+ amorphous silicon layer **3a** on the intrinsic amorphous silicon layer **3b**.

The reflective plate **13**, made of aluminum, or the like, is provided so as to cover the TFT **24** with the protection film **6** being interposed therebetween, and functions also as a light-blocking film for preventing light from entering the TFT **24**. The reflective plate **13** is provided in a floating structure, where it is electrically connected to neither the TFT **24** nor the transparent electrode **8**, or anywhere else.

The color filter **9** is made up of filter portions, each of which is made of a photosensitive resist material containing one of red, green and blue pigments dispersed therein, and is provided so as to cover the reflective plate **13** and to extend substantially entirely across each pixel area, which is defined by two adjacent gate lines **17** and two adjacent source lines **18**. A red, green or blue filter portion is provided for each pixel.

The transparent electrode **8**, made of ITO (Indium Tin Oxide), or the like, is provided so as to cover the color filter **9** and is connected to the drain electrode **5** of the TFT **24** via a contact hole **21** formed in the color filter **9**.

The counter substrate **22** includes a common counter electrode **10** made of ITO, or the like, on the glass substrate **11**.

The liquid crystal layer **12** is made of a nematic liquid crystal material having electrooptical properties.

The liquid crystal display apparatus **30** displays an image as follows. In each pixel, when a predetermined voltage is applied to the gate electrode **1** of the TFT **24** via the gate line **17**, thereby turning the TFT **24** ON, a charge flowing in via the drain electrode **5** is held by the liquid crystal capacitor formed between the transparent electrode **8** and the common counter electrode **10** and the storage capacitor as a signal voltage is applied to the source electrode **4** via the source line **18**. The orientation of the liquid crystal molecules in the liquid crystal layer **12** is changed according to the amount of charge, thereby accordingly changing the light transmissivity of the liquid crystal layer **12**, thereby displaying an image.

In the liquid crystal display apparatus **30**, the color filter **9** and the transparent electrode **8** are formed on the substrate on which the TFTs **24** are formed, i.e., the TFT array substrate **23**, whereby there is little displacement between the transparent electrode **8** and the color filter **9**, while eliminating the need to provide the color filter **9** on the counter substrate **22**. Therefore, the counter substrate **22** has a simple structure where the common counter electrode **10** is provided on the substrate. Thus, the counter substrate **22** is not divided into sections by elements on the substrate, and hardly requires any attachment margin. Furthermore, this structure eliminates the need to provide a black matrix for optically separating filter portions of different colors of the color filter **9** from one another, thereby realizing a liquid crystal display apparatus having a high definition and a high aperture ratio. Moreover, the reflective plate **13**, provided so as to cover the TFT **24**, functions as a light-blocking film for preventing light from entering the TFT **24**. This ensures a sufficient light-blocking property around the TFT **24**, thereby suppressing

the decrease in the off-state characteristics of the TFT **24**. Moreover, since the reflective plate **13** has a floating structure and is not electrically connected to any other elements, the parasitic capacitance is small and the operation of the TFT **24** is not adversely influenced. Thus, it is possible to realize a semi-transmissive liquid crystal display apparatus having a simple color-filter-on-array structure.

Next, a method for manufacturing a liquid crystal display apparatus according to Embodiment 1 of the present invention will be described.

<u>Step of producing TFT array substrate</u>

First, a metal film made of titanium, or the like, is formed by a sputtering method on the glass substrate **11** made of a non-alkaline glass, and then patterned by a photo-engraving process (hereinafter referred to as "PEP") to form the gate lines **17**, the gate electrodes **1** and the storage capacitor lines **19**.

Then, silicon nitride, or the like, is deposited by a CVD (Chemical Vapor Deposition) method on the gate lines **17**, the gate electrodes **1** and the storage capacitor lines **19** to form the gate insulating film **2**.

Then, an intrinsic amorphous silicon film and a phosphorus-doped n+ amorphous silicon film are successively formed on the gate insulating film **2** by a CVD method, and then patterned into an island-shaped pattern by PEP, thereby forming the semiconductor film **3** including the intrinsic amorphous silicon layer **3b** and the n+ amorphous silicon layer **3a**.

Then, a metal film made of titanium, or the like, is formed by a sputtering method on the gate insulating film **2**, on which the semiconductor film **3** has been formed, and then patterned by PEP to form the source lines **18**, the source electrodes **4** and the drain electrodes **5**.

Then, the n+ amorphous silicon layer **3a** is etched by using the source

electrode **4** and the drain electrode **5** as a mask, thereby forming a channel section.

Then, silicon nitride, or the like, is deposited by a CVD method on the source electrodes **4** and the drain electrodes **5**, thereby forming the protection film **6**.

Then, a metal film made of aluminum, or the like, is formed by a sputtering method on the protection film **6**, and then patterned by PEP to form the reflective plate **13** covering the TFT **24**.

Then, a photosensitive resist material, or the like, containing one of red, green and blue pigments dispersed therein is applied on the protection film **6** and the reflective plate **13**, and then patterned by PEP to form filter portions of the selected color. The step is repeated for the other two colors, thus forming the color filter **9** including filter portions of three colors such that a filter portion of one color is provided for each pixel.

Then, the contact hole **21** is formed by PEP so that it runs through the color filter **9** and the protection film **6** to reach the drain electrode **5**.

Then, a transparent conductive film made of ITO, or the like, is formed by a sputtering method on the color filter **9**, and then patterned by PEP to form the transparent electrodes **8**.

Thus, the TFT array substrate **23** is produced.

<u>Step of producing counter substrate</u>

The counter substrate **22** can be produced by forming a transparent conductive film made of ITO, or the like, by a sputtering method on the glass substrate **11** made of a non-alkaline glass.

<u>Step of producing liquid crystal display apparatus</u>

First, a polyimide resin, or the like, is applied on the TFT array substrate **23** and the counter substrate **22** by flexography, and then baked. Then, an alignment process

is performed by rubbing the surface of the alignment film in a predetermined direction.

Then, a sealant made of a thermosetting epoxy resin, or the like, is applied by screen printing on one of the TFT array substrate **23** and the counter substrate **22** in a frame-shaped pattern broken at the liquid crystal injection port. Spherical plastic beads made of a polymer such as a polystyrene polymer are dispersed on the other one of the TFT array substrate **23** and the counter substrate **22**. The diameter of the spherical plastic beads corresponds to the thickness of the liquid crystal layer.

Then, the TFT array substrate **23** and the counter substrate **22** are attached to each other, and the sealant is cured to form an empty cell. The color filter **9** and the transparent electrode **8** are formed on the TFT array substrate **23**, whereby there is little displacement between the color filter **9** and the transparent electrode **8**, while eliminating the need to provide the color filter **9** on the counter substrate **22**. Therefore, the counter substrate **22** has a simple structure where the common counter electrode **10** is provided on the substrate. Thus, even if there is some misalignment between the TFT array substrate **23** and the counter substrate **22** when attaching them together, the misalignment does not lead to a displacement between the color filter **9** and the transparent electrode **8**. Therefore, the liquid crystal display apparatus **30** provides a desirable productivity because it is not necessary to perform the substrate attachment step with a high precision.

Then, a liquid crystal material is injected into the gap between the TFT array substrate **23** and the counter substrate **22** of the empty cell by a vacuum filling method, thereby forming the liquid crystal layer **12**. Then, a UV-curable resin is applied to the liquid crystal injection port, and is irradiated with UV light to cure the UV-curable resin, thereby sealing the injection port.

The liquid crystal display apparatus **30** of the present invention can be manufactured as described above.

As described above, the liquid crystal display apparatus **30** of the present

invention provides a desirable productivity because it is not necessary to perform the substrate attachment step with a high precision. Furthermore, this structure eliminates the need to provide a black matrix for optically separating filter portions of different colors of the color filter from one another, thereby realizing a semi-transmissive liquid crystal display apparatus having a high definition and a high aperture ratio.

EMBODIMENT 2

A semi-transmissive liquid crystal display apparatus according to Embodiment 2 of the present invention will now be described with reference to FIG. **2**. Note that FIG. **2** is a schematic cross-sectional view illustrating the TFT array substrate **23** of the liquid crystal display apparatus **30** according to Embodiment 2 of the present invention, and corresponds to FIG. **3**.

In the liquid crystal display apparatus **30**, the interlayer insulating film **14** is provided between the color filter **9** and the transparent electrode **8** so as to cover the reflective plate **13**. Other than this, the liquid crystal display apparatus **30** of the present embodiment is similar to that of Embodiment 1, and common components will be denoted by the same reference numerals and will not be further described below.

The interlayer insulating film **14** is made of a photosensitive acrylic resin, or the like. The thickness of the interlayer insulating film **14** is determined so that the total optical path length for light traveling through the transmissive region is substantially equal to that for light traveling through the reflective region. Therefore, the thickness dt of the liquid crystal layer **12** in the transmissive region is about twice the thickness dr of the liquid crystal layer **12** in the reflective region.

Thus, in the liquid crystal display apparatus **30**, the interlayer insulating film **14** for matching the total optical path length for light traveling through the transmissive region with that for light traveling through the reflective region is provided between the

color filter **9** and the transparent electrode **8** so as to cover the reflective plate **13**. As a result, in addition to the functions and effects of Embodiment 1, the liquid crystal display apparatus **30** of the present embodiment can maintain a desirable display quality without causing a phase difference between the transmissive region and the reflective region.

A method for manufacturing the liquid crystal display apparatus **30** according to Embodiment 2 of the present invention will not be described in detail as it is similar to that of Embodiment 1, except for the additional formation of the interlayer insulating film **14** on the color filter **9**.

A specific method for forming the interlayer insulating film **14** will now be described.

First, a photosensitive acrylic resin, or the like, is applied on the color filter **9**, and then patterned by PEP to form the interlayer insulating film **14** in a pattern corresponding to the pattern of the reflective plate **13**.

Then, a transparent conductive film made of ITO, or the like, is formed by a sputtering method on the color filter **9** and the interlayer insulating film **14**, and then patterned by PEP to form the transparent electrode **8**.

In this way, the interlayer insulating film **14** for matching the total optical path length for light traveling through the transmissive region with that for light traveling through the reflective region can be formed between the color filter **9** and the transparent electrode **8**, thereby realizing a semi-transmissive liquid crystal display apparatus that provides a desirable display quality without causing a phase difference between the transmissive region and the reflective region.

While the TFT array substrate and the counter substrate are both produced from a base substrate made of a glass in the embodiments described above, the present invention is not limited to this. Typically, a plastic substrate can easily shrink/expand due to heat, moisture, etc. Therefore, if a plastic substrate is used as a base substrate, a

misalignment is likely to occur when attaching the substrates to each other. According to the present invention, however, it is not necessary to perform the substrate attachment step with a high precision. Therefore, the attachment step is easy even if a plastic substrate is used. Thus, the advantages of the present invention may be more pronounced when the TFT array substrate and the counter substrate are produced from a base substrate made of a plastic material.

While the present invention has been described in preferred embodiments, it will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than those specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention that fall within the true spirit and scope of the invention.